

DYNAMIC SIMULATION OF MULTICOMPONENT SEPARATION IN COMPLEX DISTILLATION COLUMNS

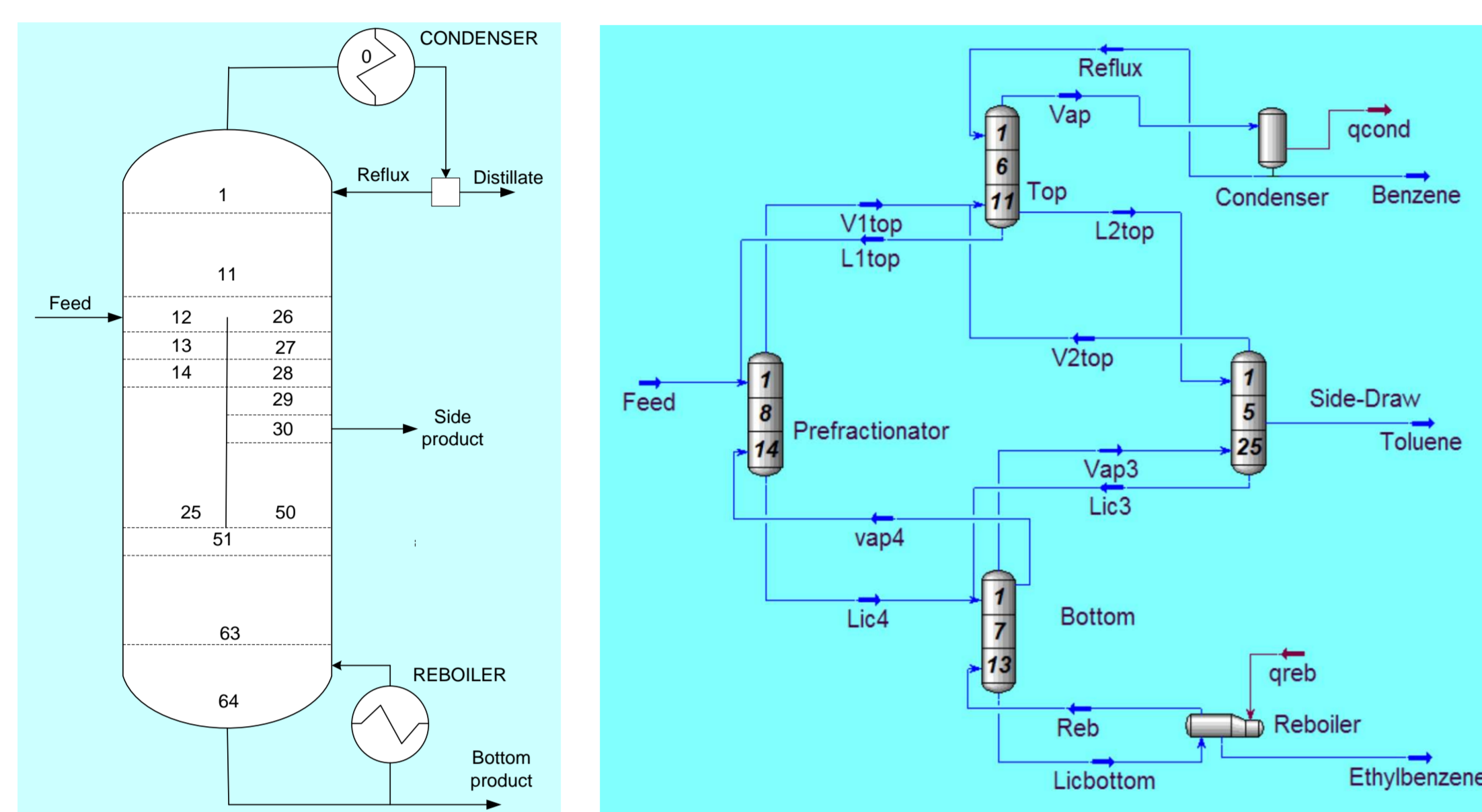
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OBJECTIVES

A divided wall distillation column (DWC), designated to the separation of a ternary hydrocarbon mixture was designed and optimised using HYSYS® simulator by a trial and error method. Using an original dynamic model, the start-up time was investigated and also the influence of main operating parameters, such as the reflux ratio, feed composition and flow, side-draw flow and reboiler duty on the performance of the DWC.

MODEL FORMULATION

Physical model and HYSYS representation



- Feed composition in mol fractions: **0.6/ 0.3 /0.1**;
- Conditions: product purities in mol fraction above **0.95**;
- Ternary mixture: **benzene, toluene, ethylbenzene**;
- Topology established in the frame of HYSYS® simulator.

Dynamic Distillation Model

$$\text{Mass balance on plate } j \quad \frac{dN_j}{dt} = L_{j-1} + V_{j+1} - L_j - V_j \pm F_{L,j} \pm F_{V,j}$$

$$\text{Component } i \text{ mass balance on plate } j \quad \frac{d(N_j x_{i,j})}{dt} = L_{j-1} x_{i,j-1} + V_{j+1} y_{i,j+1} - L_j x_{i,j} - V_j y_{i,j} \pm F_{L,j} x_{F,i,j} \pm F_{V,j} y_{F,i,j}$$

$$\text{Temperature calculation on plate } j \quad \frac{dT_j}{dt} = - \frac{\sum_{i=1}^m \frac{\gamma_{i,j} P_{i,j}}{P_j} \left(1 + \frac{x_{i,j}}{\gamma_{i,j}} \frac{d\gamma_{i,j}}{dx_{i,j}} \right) dx_{i,j}}{\sum_{i=1}^m \frac{x_{i,j} \gamma_{i,j}}{P_j} \frac{dP_{i,j}}{dT_j}}$$

The vapour flow rate V_j is obtained from the total energy balance:

$$V_j = \frac{1}{H_j} \left(L_{j-1} h_{j-1} + V_{j+1} H_{j+1} - L_j h_j \pm F_{L,j} h_{F,j} \pm F_{V,j} H_{F,j} - q_j - \frac{dh_j}{dT_j} \frac{dT_j}{dt} - h_j \frac{dN_j}{dt} \right)$$

The pressure drop is calculated on the base of hydraulic correlations:

$$\Delta p_j = - \frac{0.00683}{\rho_{G,j}} \left(\frac{Q_{G,j} \sum_{i=1}^3 y_{i,j} M_i}{A_o} \right)^2 - 0.02175 \frac{\sigma_j}{d_o} - 0.07352 \rho_{L,j} z_{st,j}$$

RESULTS

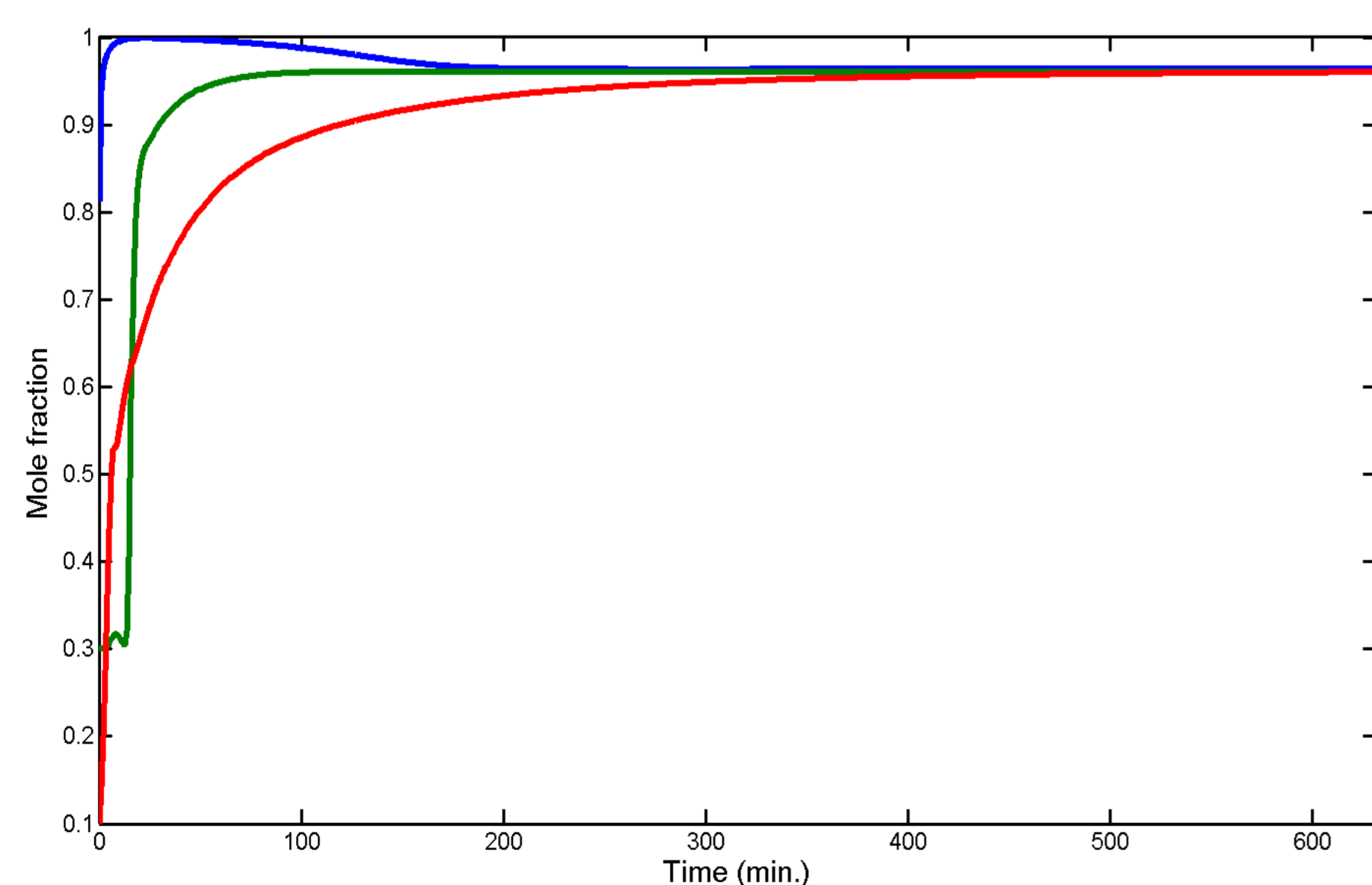
Components mole fractions in the DWC products

		Top product		
	Benzene	Toluene	Ethylbenzene	
HYSYS	0.9613	0.0387	~10 ⁻⁶	
DDM at stationary state	0.9632	0.0368	~10 ⁻⁶	
		Side product		
	Benzene	Toluene	Ethylbenzene	
HYSYS	0.0106	0.9612	0.0282	
DDM at stationary state	0.0042	0.9600	0.0358	
		Bottom product		
	Benzene	Toluene	Ethylbenzene	
HYSYS	~10 ⁻⁸	0.0463	0.9537	
DDM at stationary state	~10 ⁻⁸	0.0402	0.9598	

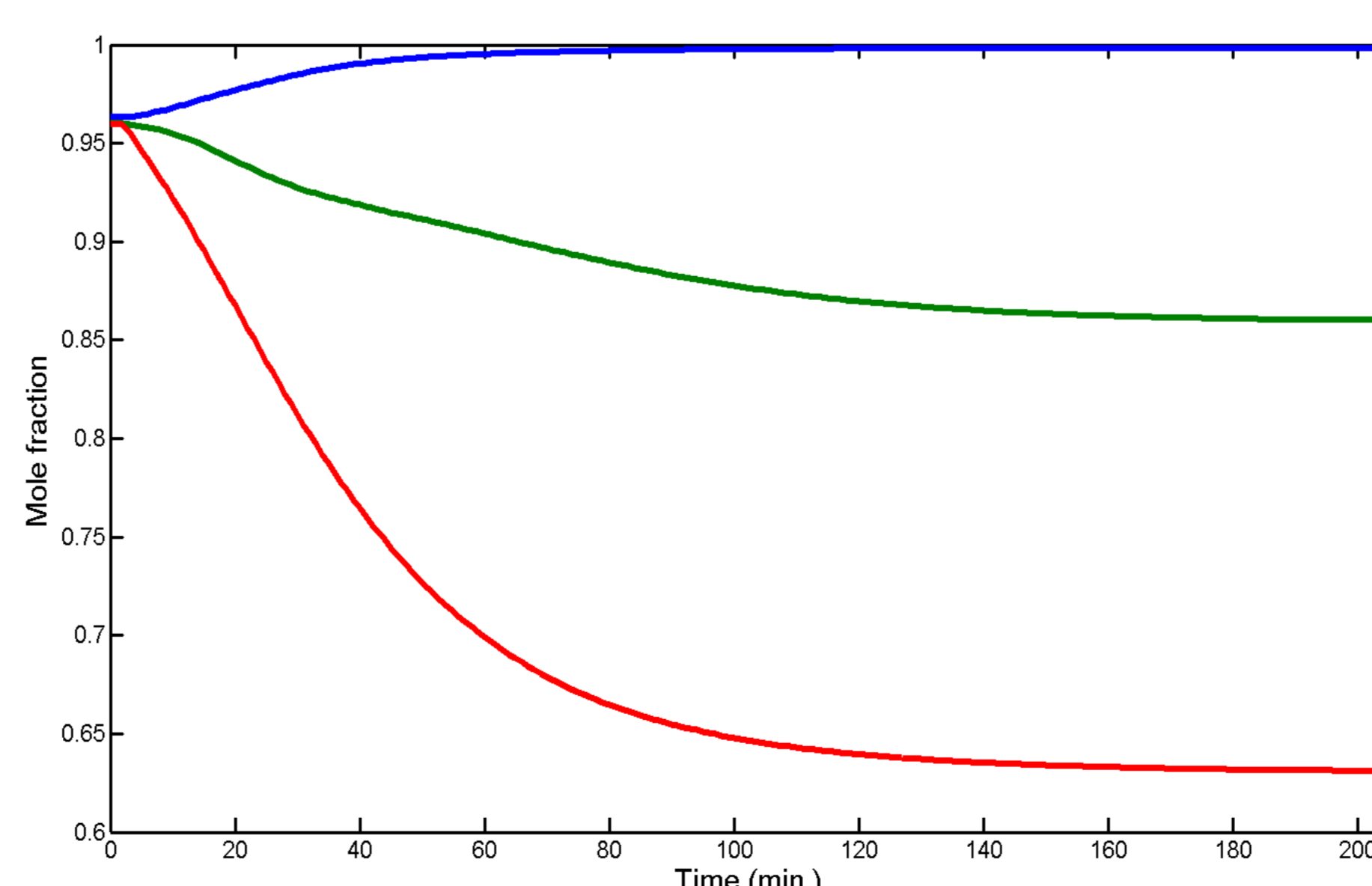
Effects of step signals

Step signal	Benzene mole fraction in top product at the new stationary state	Toluene mole fraction in side product at the new stationary state	Ethylbenzene mole fraction in top product at the new stationary state
Increasing the feed flowrate with 10%	I 0.9981	D 0.8599	D 0.6309
Decreasing the feed flowrate with 10%	D 0.8707	D 0.7410	I 0.9999
Increasing the reboiler duty with 10%	D 0.8793	D 0.7648	I 0.9998
Decreasing the reboiler duty with 10%	I 0.9986	D 0.8415	D 0.6087
Increasing the side-draw flowrate with 10%	0.9630	D 0.8841	I 0.9994
Decreasing the side-draw flowrate with 10%	0.9622	I 0.9610	D 0.7546

I – the value at the new stationary state is increased in comparison with the value at initial stationary state;
D – the value at the new stationary state is decreased in comparison with the value at initial stationary state



Evolution during the start-up transient regime of benzene concentration in top product (—), of toluene in side product (—), and of ethylbenzene in bottom product (—).



Benzene in top product (—), toluene in side product (—), and ethylbenzene in bottom product (—) concentrations responses for increasing step signal (10%) of feed flowrate.

CONCLUSIONS

- The step signals investigated proved that a complex distillation column is sensitive to variations of operating parameters that can occur in industrial exploitation and a reliable control system is necessary.
- The dynamic evolution of a DWC is similar to that of a conventional distillation column and the internal recycle streams do not affect the dynamic behaviour.